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(54) INLET DESIGN FOR A PUMP ASSEMBLY

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F04D 29/42 (2006.01)
F04D 29/44 (2006.01)
F04D 29/70 (2006.01)

(52) **U.S. Cl.**

CPC ***F04D 23/008*** (2013.01); ***F04D 29/4213*** (2013.01); ***F04D 29/441*** (2013.01); ***F04D 29/701*** (2013.01); *F05D 2250/51* (2013.01)

(58) **Field of Classification Search**

CPC F04D 5/002; F04D 5/007; F04D 23/008; F04D 29/701; F04D 29/441; F04D 29/4213; F05B 2250/503; F05B 2250/50; F05B 2250/501

USPC 415/1, 52.1, 55.1, 55.2, 55.3, 55.4, 58.2,415/58.3, 184, 5.5, 55.7

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,056,553	A	*	10/1936	Abramson	415/184
2,724,338	A	*	11/1955	Roth	415/55.5
2,842,062	A	*	7/1958	Wright	415/11
3,915,589	A	*	10/1975	Vander Linden	415/55.4
4,306,833	A	*	12/1981	Sixsmith	F04D 5/002 415/55.3
4,334,821	A	*	6/1982	Sixsmith	F04D 5/002 415/55.1
4,408,952	A	*	10/1983	Schweinfurter	415/55.6
6,974,301	B2	*	12/2005	Suzuki et al.	415/55.1
7,513,741	B2	*	4/2009	Smiley et al.	415/205
7,837,430	B2	*	11/2010	Cattani	415/55.2
2004/0096316	A1	*	5/2004	Simon et al.	415/151
2009/0047125	A1	*	2/2009	Chien	415/208.1
2010/0086396	A1		4/2010	Peterson et al.	
2010/0172777	A1		7/2010	Adhvaryu et al.	
2012/0294703	A1	*	11/2012	Lei et al.	415/1

OTHER PUBLICATIONS

U.S. Appl. No. 13/363,946, filed Feb. 1, 2012 ; Title: Inlet Design for a Pump Assembly ; Inventors : Ketan G.Adhvaryu, Murray Busato, Robert D. Keefover, Brian M. Chomicz.

* cited by examiner

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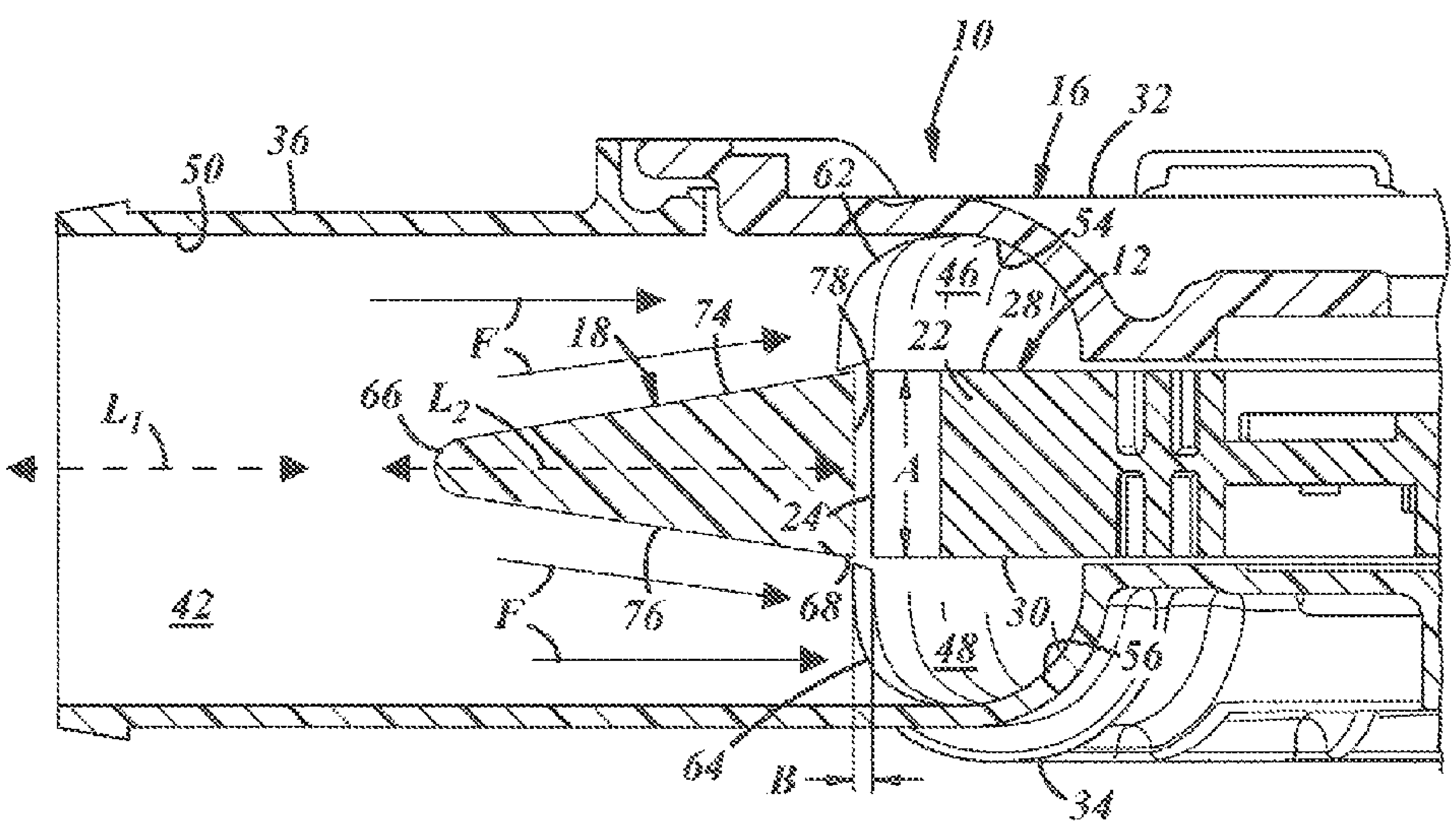
(57) **ABSTRACT**

One embodiment includes an air pump assembly (**10**) with an impeller (**12**), a housing (**16**), and a diverter (**18**). The impeller (**12**) has an axis of rotation (R). The housing (**16**) surrounds the impeller (**12**) and has an inlet passage (**42**) with a longitudinal axis (L_1) arranged generally orthogonal to the axis of rotation (R) of the impeller (**12**). The diverter (**18**) helps reduce turbulent fluid-flow in the inlet passage (**42**).

20 Claims, 6 Drawing Sheets



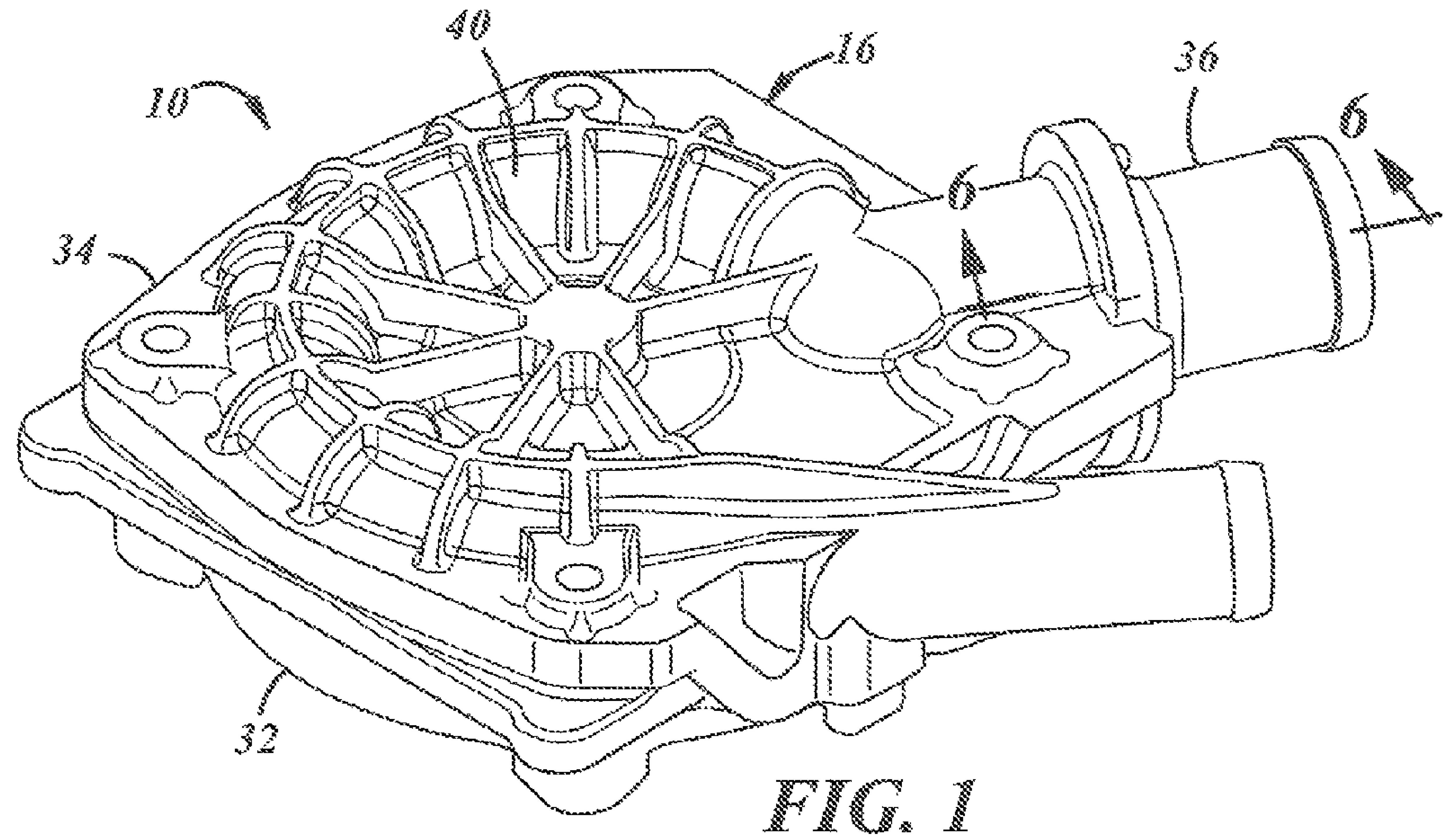


FIG. 1

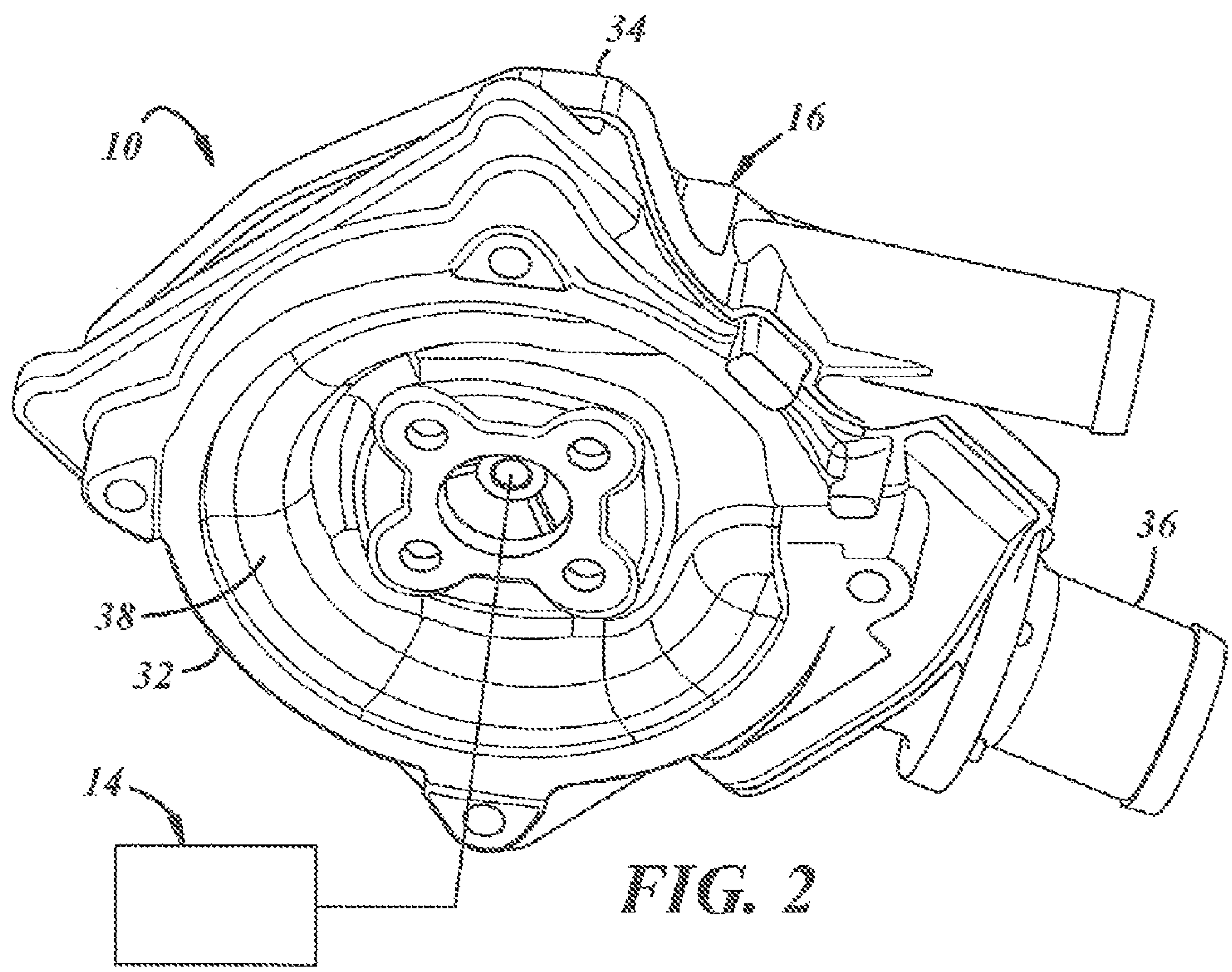
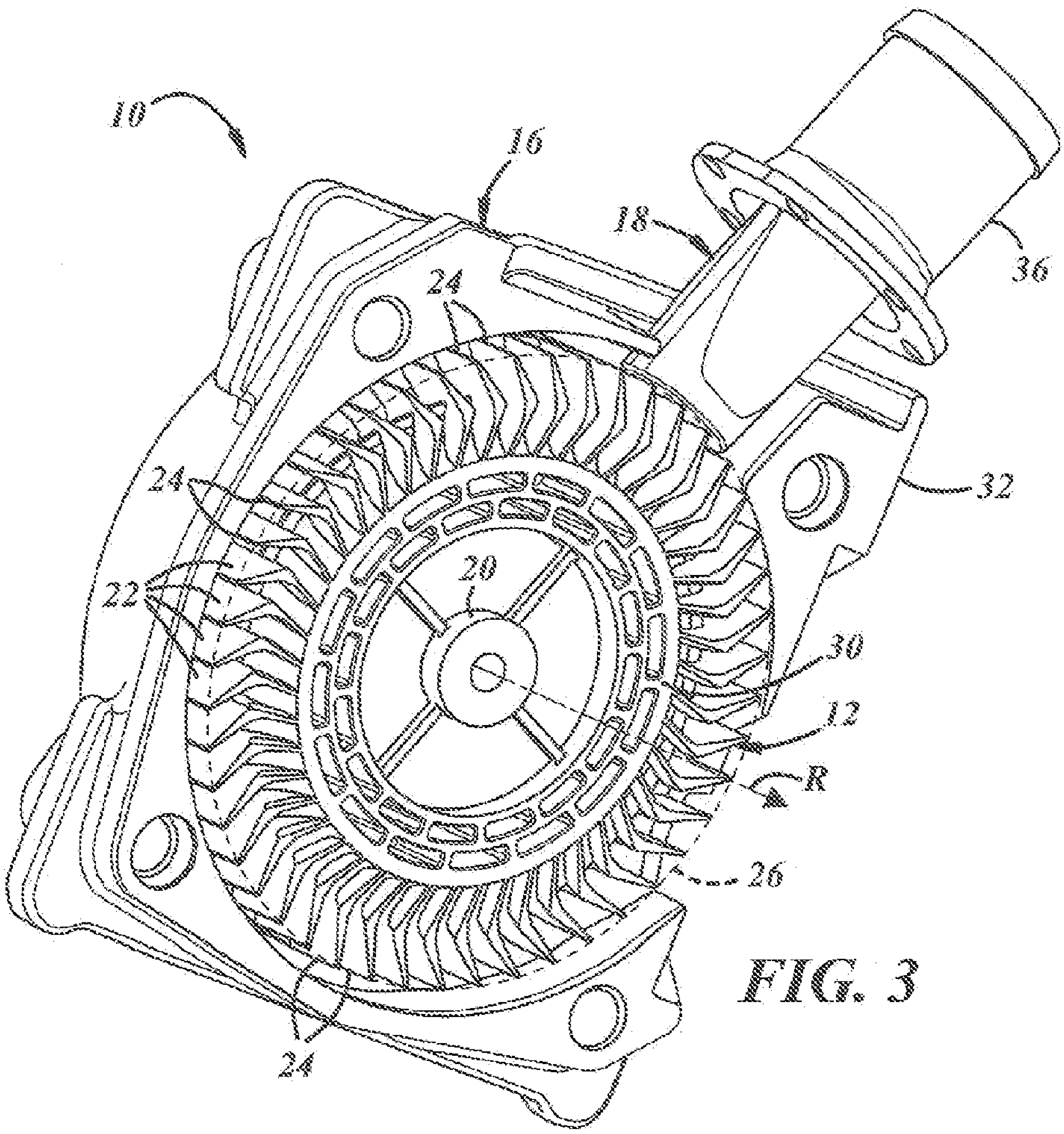


FIG. 2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16
18
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12
R
26
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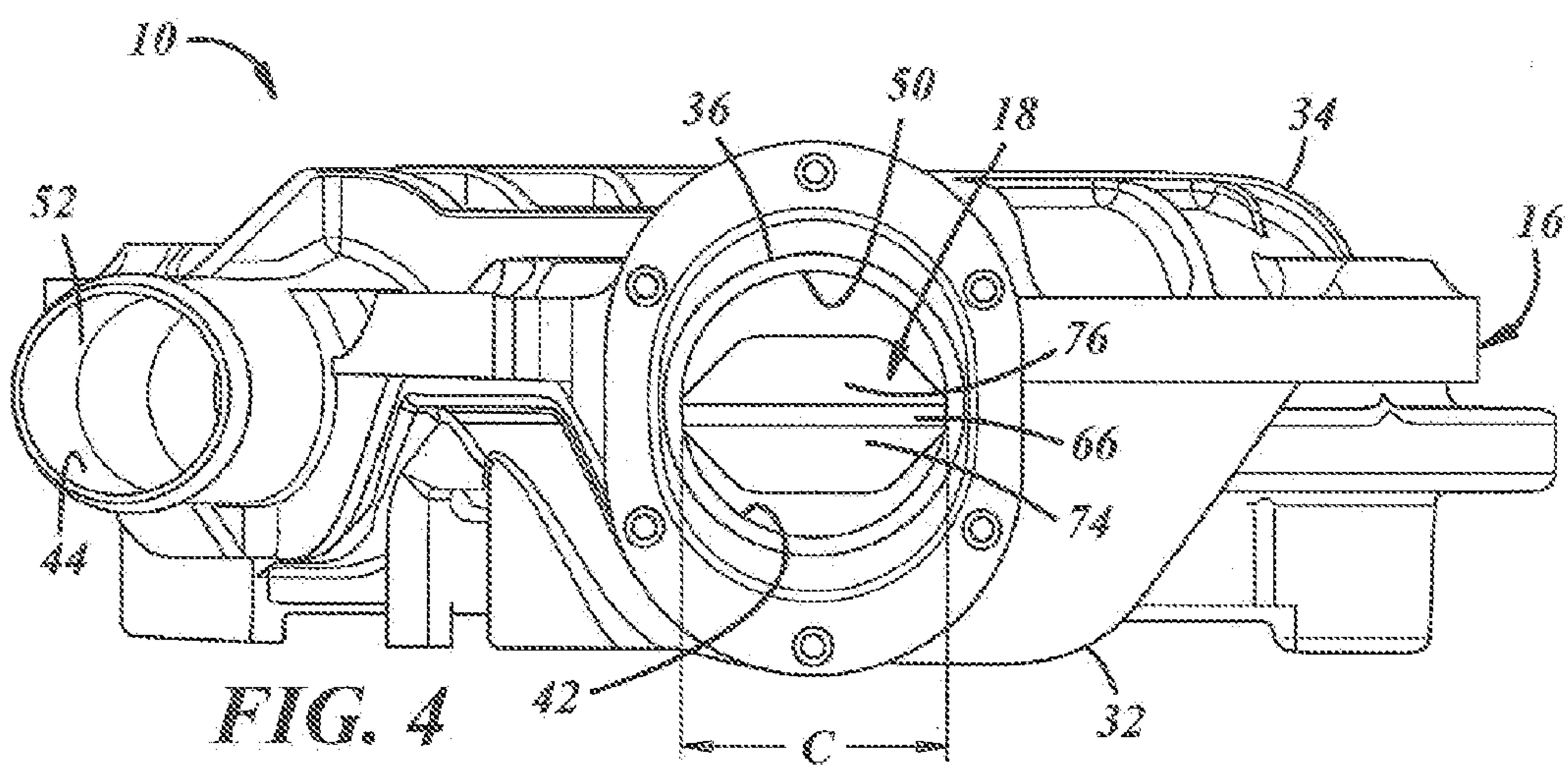
24

FIG. 3


10
36
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18
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52
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76
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74
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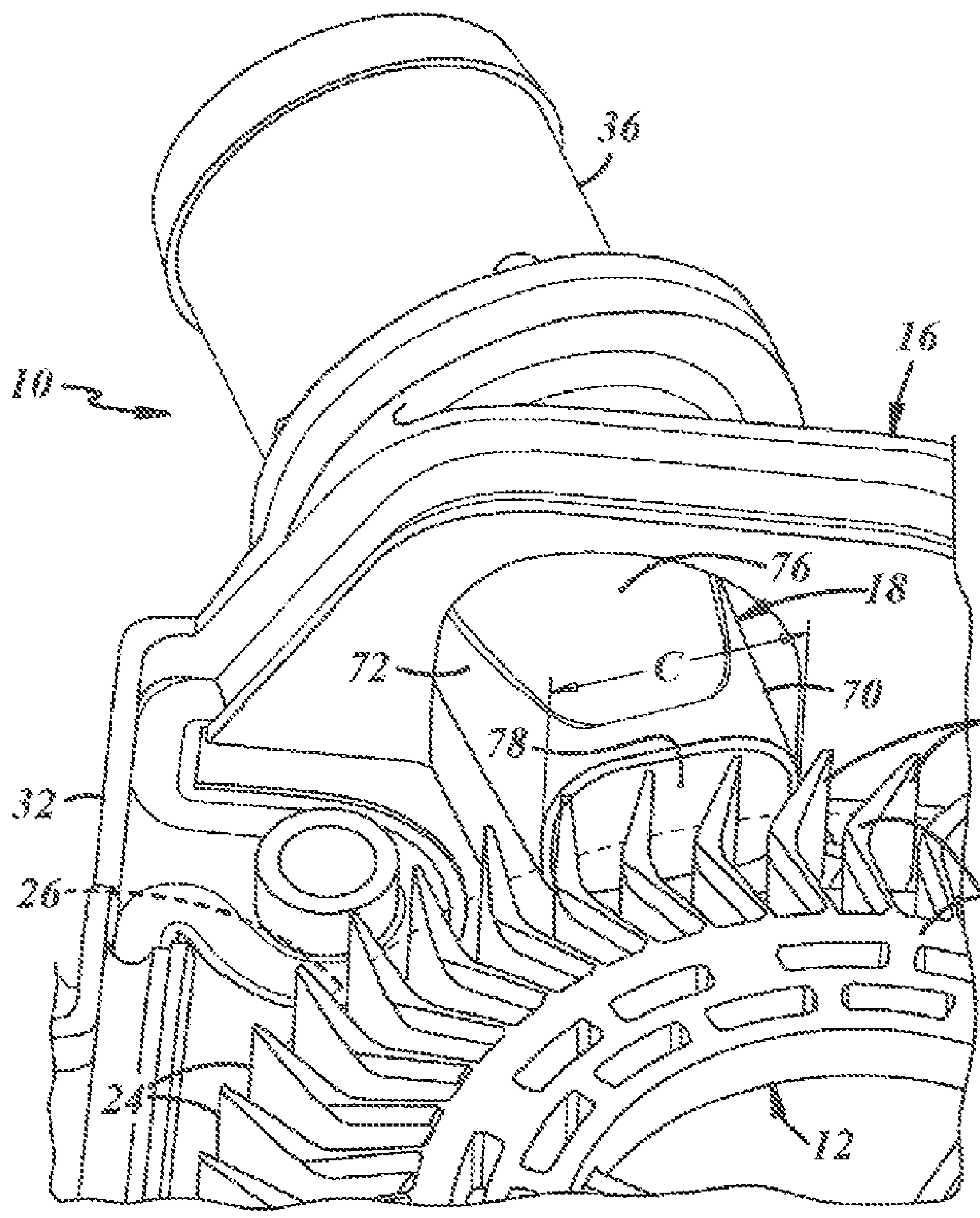
42
C
32

FIG. 4


36
16
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76
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72
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78
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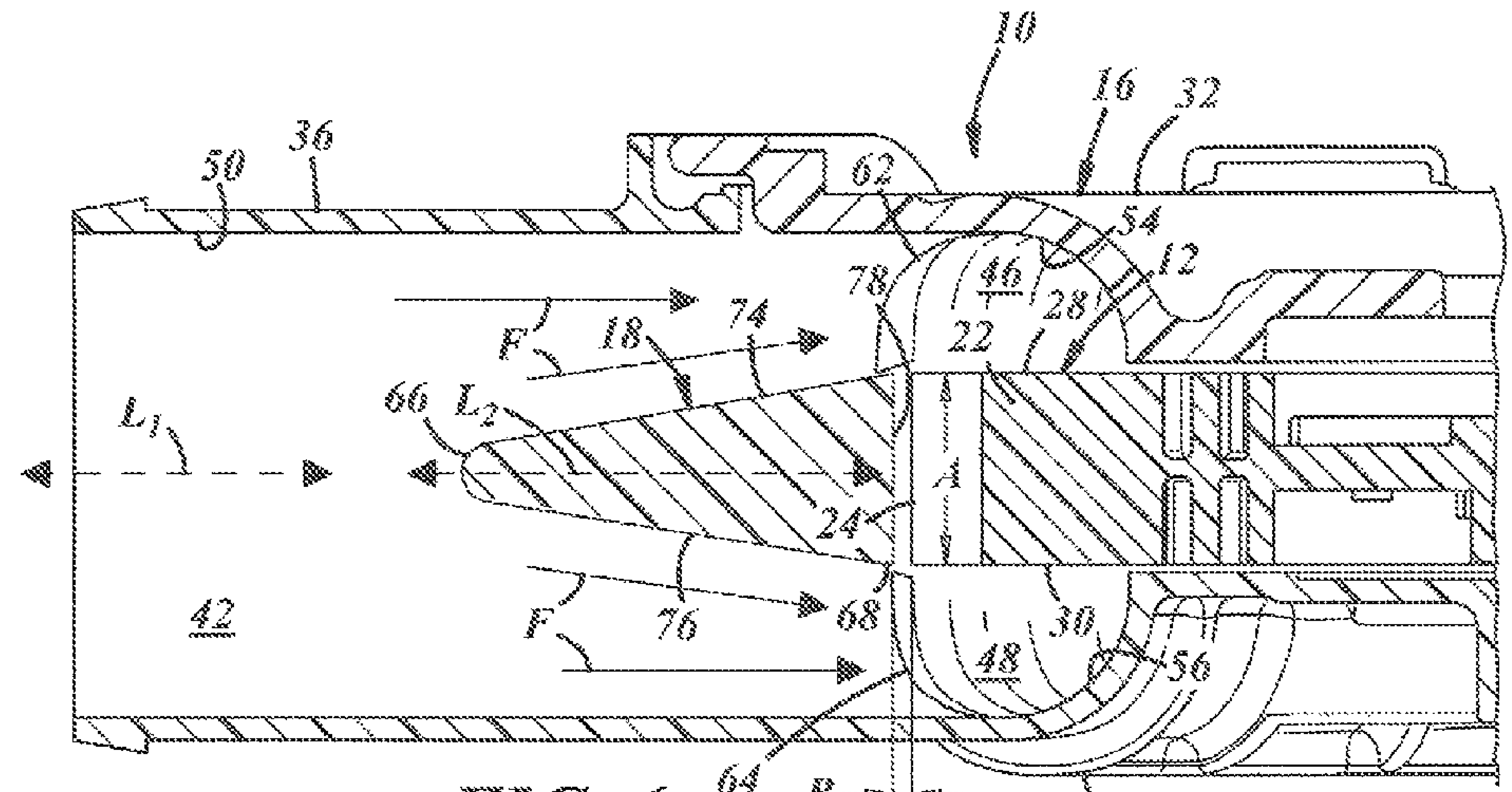
12

FIG. 5


10
16
32
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62
54
46
12
78
28
F
18
74
22
66
L_2
L_1
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42
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B
34

FIG. 6

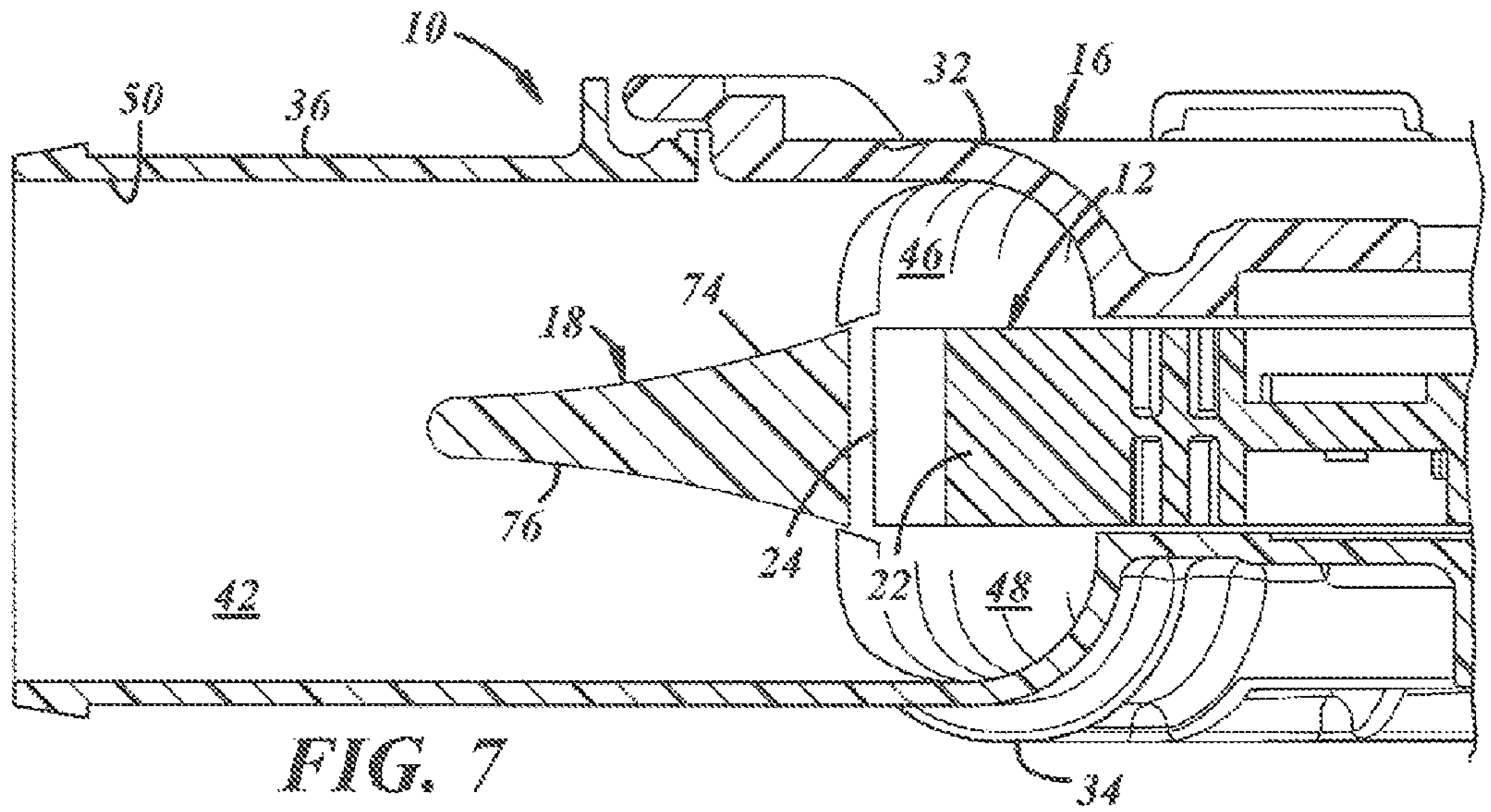

FIG. 7

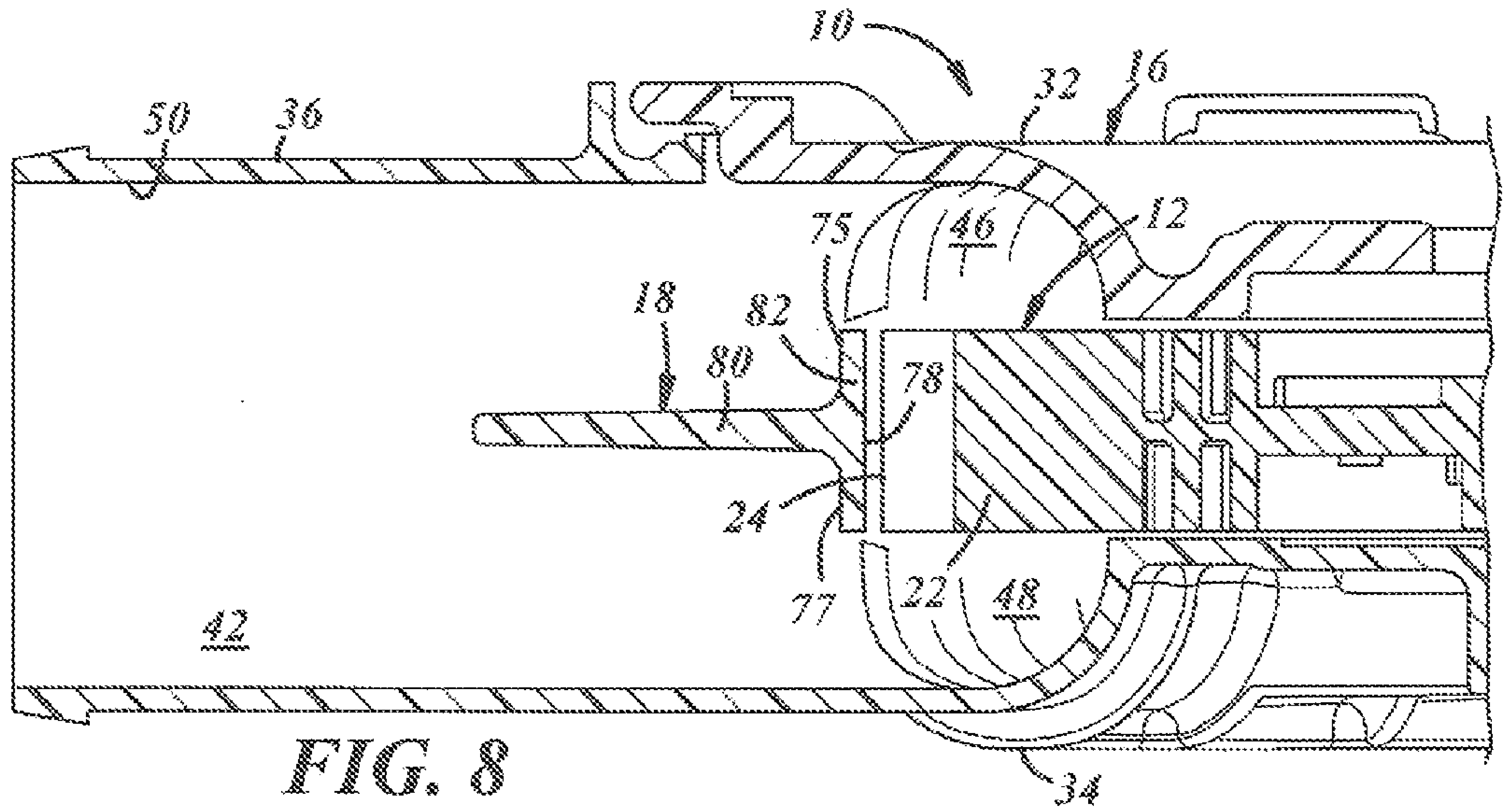

FIG. 8

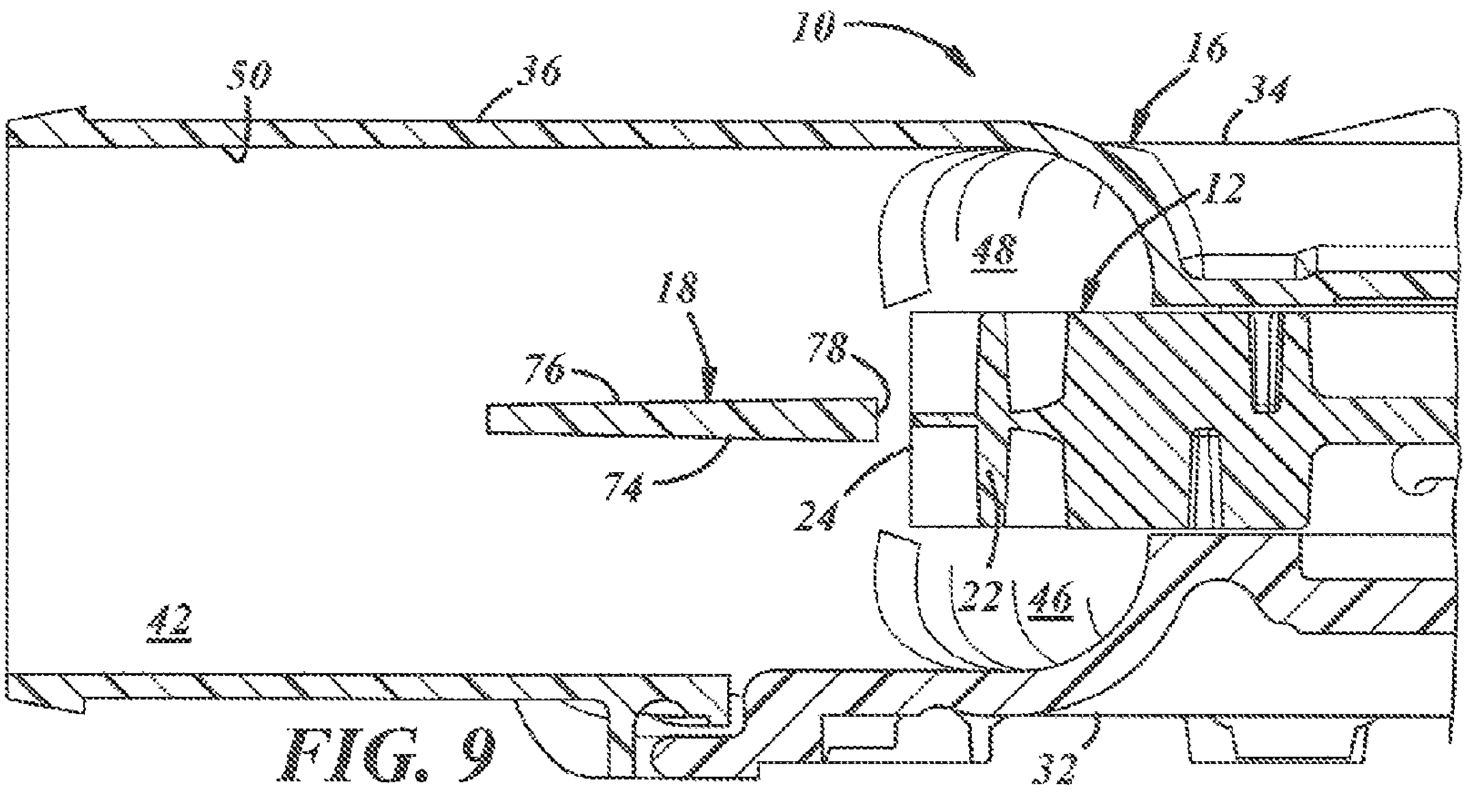

FIG. 9

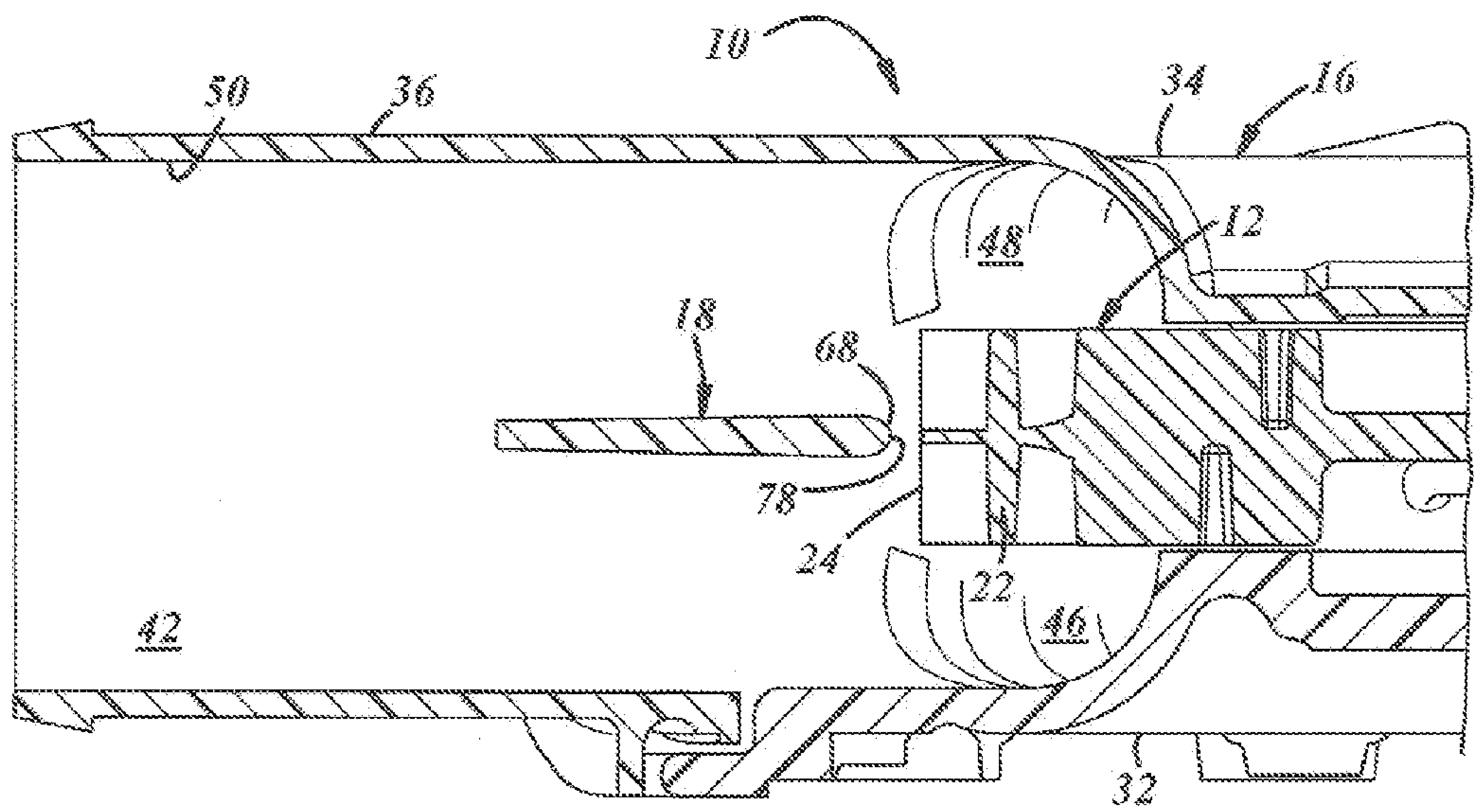
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FIG. 10

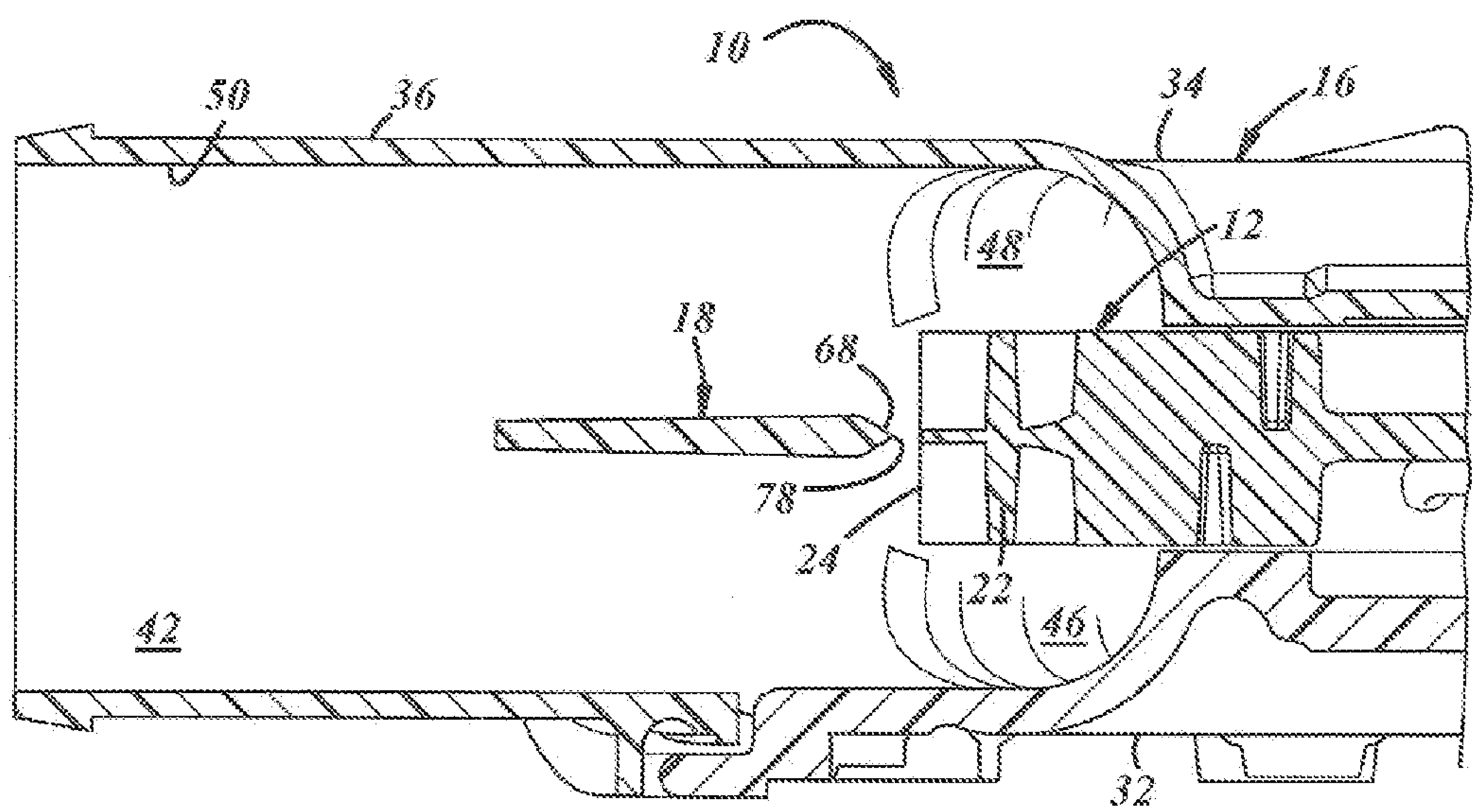
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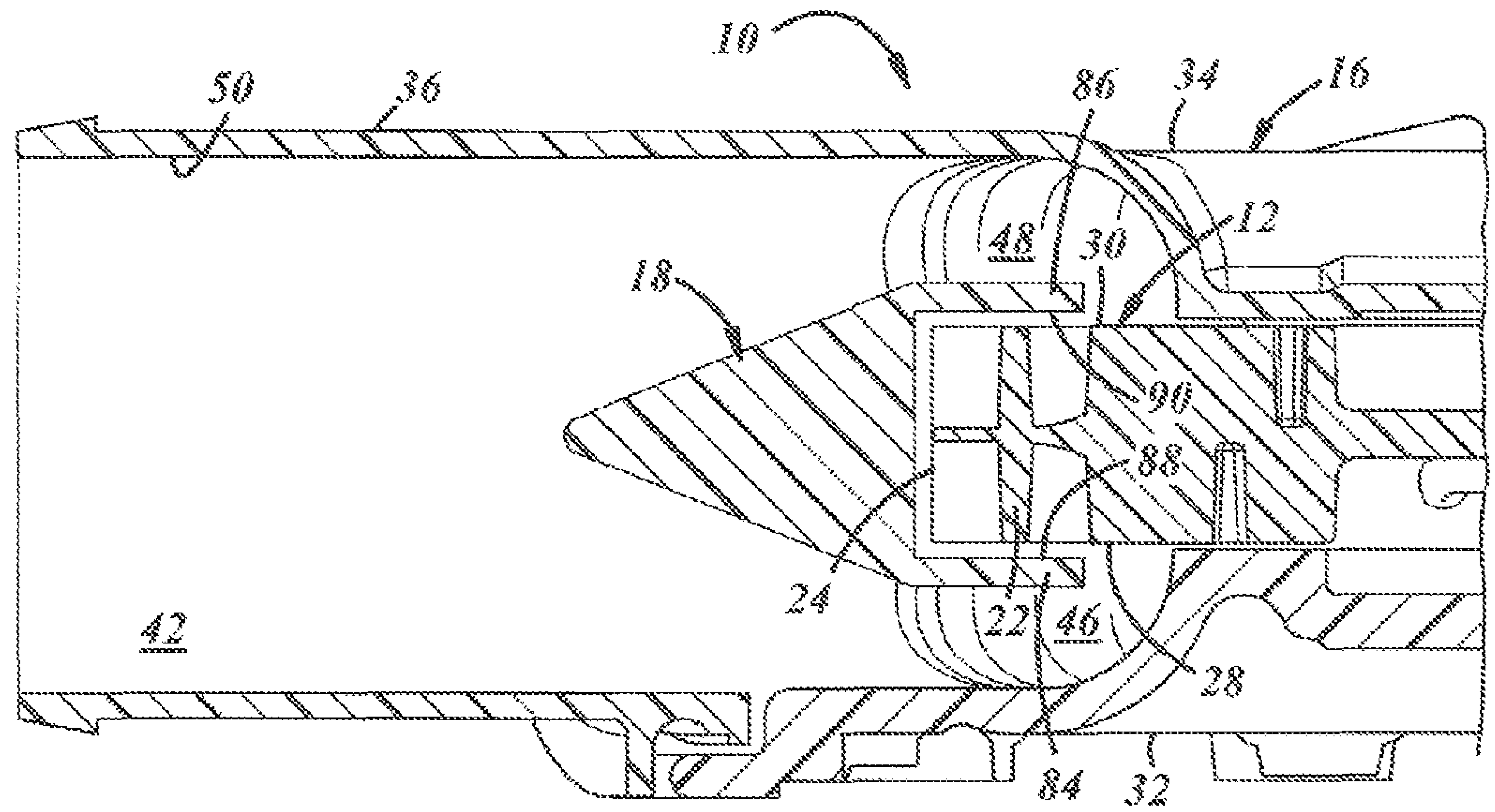
FIG. 11


10
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88
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22
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42
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84
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FIG. 12

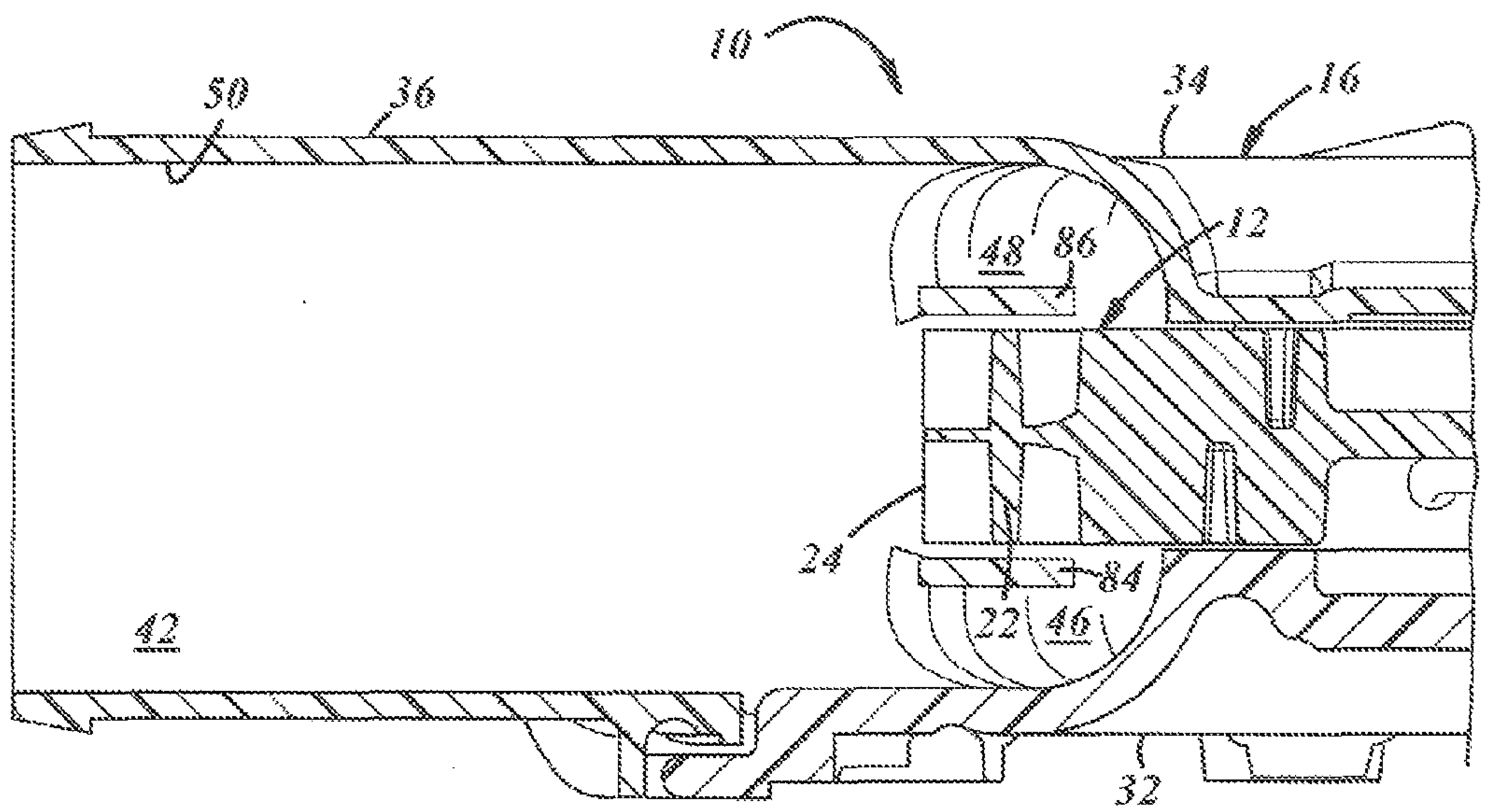
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FIG. 13

INLET DESIGN FOR A PUMP ASSEMBLY

TECHNICAL FIELD

The technical field generally relates to inlet designs for pump assemblies.

BACKGROUND

Pump assemblies having impellers are sometimes designed with an inlet passage that feeds fluid orthogonally relative to an axis of rotation of the impeller. One example of such a pump assembly is a secondary air pump assembly that supplies secondary or intake air to an automotive exhaust system during warm-up of an automotive internal combustion engine, or at other times.

SUMMARY OF ILLUSTRATIVE EMBODIMENTS

One embodiment includes an air pump assembly that may include an impeller, a housing, and a diverter. The impeller may have an axial face, an axis of rotation, and a circumferential periphery. The housing may surround the impeller. The housing may form a part or more of a primary passage for air flow during use of the air pump assembly. The primary passage may be open to the impeller at the axial face of the impeller. The housing may have an inlet passage that may communicate with the primary passage. The inlet passage may have a longitudinal axis that may be arranged generally orthogonal to the axis of rotation of the impeller. The diverter may be located near or closer to the inlet passage. The diverter may have a surface that confronts the axial face of the impeller, that confronts the circumferential periphery of the impeller, or that confronts both the axial face and the circumferential periphery. When the air pump assembly is in use, the diverter may inhibit the generation of turbulent flow between incoming air flow and the impeller where the surface confronts the impeller.

One embodiment includes a method. The method may include providing an air pump assembly that may comprise an impeller and a housing. The impeller may have numerous vanes, an axial face, and an axis of rotation. The vanes may have a circumferential periphery. The housing may form a part or more of a primary passage. The primary passage may be open to the vanes at the axial face. The housing may have an inlet passage with a longitudinal axis that may be arranged generally orthogonal to the axis of rotation of the impeller. The method may also include diverting a portion or more of incoming air flow through the inlet passage away from the circumferential periphery of the vanes, away from the axial face of the impeller, or away from both of the circumferential periphery and the axial face.

One embodiment includes an air pump assembly that may include an impeller, a motor, a housing, and a diverter. The impeller may have numerous vanes, a first axial face, a second axial face, and an axis of rotation. The vanes may have a circumferential periphery. The motor may be connected to the impeller in order to rotate the impeller during use of the air pump assembly. The housing may surround the impeller. The housing may form a part or more of a first primary passage and a part or more of a second primary passage. The first primary passage may be open to the vanes at the first axial face, and the second primary passage may be open to the vanes at the second axial face. The housing may have an inlet passage that may communicate with the first and second primary passages. The housing may have an

outlet passage that may communicate with the first and second primary passages. The inlet passage may have a longitudinal axis that may be arranged generally orthogonal to the axis of rotation of the impeller. The diverter may have a surface that may confront the circumferential periphery of the vanes. The surface may have an axial height dimension that may be greater than approximately one-half an axial height dimension of the vanes at the circumferential periphery. The surface may have a circumferential width dimension that may be greater than approximately one-half a diameter dimension of the inlet passage. When the air pump assembly is in use, the diverter may inhibit incoming air flow at the circumferential periphery of the vanes where the surface confronts the circumferential periphery, and the diverter may veer incoming air flow to the first and second primary passages.

Other illustrative embodiments of the invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while disclosing illustrative embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative embodiments of the present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** is a top perspective view of an embodiment of an air pump assembly.

FIG. **2** is a bottom perspective view of the air pump assembly of FIG. **1**.

FIG. **3** is a top view of the air pump assembly of FIG. **1** with a cover removed to show an impeller.

FIG. **4** is a side view of the air pump assembly of FIG. **1**.

FIG. **5** is an enlarged view of the air pump assembly of FIG. **1** with a cover removed to show an impeller.

FIG. **6** is a cross-sectional view of the air pump assembly of FIG. **1**, showing an embodiment of a diverter.

FIG. **7** is a cross-sectional view similar to that of FIG. **6**, showing another embodiment of a diverter.

FIG. **8** is a cross-sectional view similar to that of FIG. **6**, showing another embodiment of a diverter.

FIG. **9** is a cross-sectional view similar to that of FIG. **6**, showing another embodiment of a diverter.

FIG. **10** is a cross-sectional view similar to that of FIG. **6**, showing another embodiment of a diverter.

FIG. **11** is a cross-sectional view similar to that of FIG. **6**, showing another embodiment of a diverter.

FIG. **12** is a cross-sectional view similar to that of FIG. **6**, showing another embodiment of a diverter.

FIG. **13** is a cross-sectional view similar to that of FIG. **6**, showing another embodiment of a diverter.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The following description of the embodiment(s) is merely illustrative in nature and is in no way intended to limit the invention, its application, or its uses.

The figures illustrate several embodiments of an inlet design for a pump assembly that may improve fluid-flow efficiencies through the pump assembly compared to known inlet designs, meaning that the inlet designs disclosed herein may produce greater volumetric flow rate for a given power input. The overall size of the pump assembly may therefore be reduced if suitable and desirable for a particular application, while maintaining the same fluid-flow performance of the larger pump assembly with the known inlet design. Of course, the overall size of the pump assembly with the inlet designs disclosed herein need not be reduced, in which case the pump assembly would simply exhibit improved fluid-flow efficiencies and improved performance. The improvements result in part from a reduction in turbulence of incoming fluid-flow, as will be described in greater detail below.

Referring to FIG. **1**, the inlet designs described herein may be incorporated into a pump assembly **10**. In the embodiments shown in the figures, the pump assembly **10** may be a secondary air pump assembly that is used in a secondary air system of an automotive internal combustion engine exhaust system. Secondary air systems are equipped in engine exhaust systems of automotive internal combustion engines in order to supply intake air to the engines during warm-up modes, during other engine modes, or both. Depending upon the particular application, other components of secondary air systems may include an air filter, an air valve, a catalytic converter, a diesel particulate filter, or a combination thereof. Skilled artisans will understand the general construction, arrangement, and operation of these components and others of secondary air systems such that a more detailed description need not be provided here.

The pump assembly **10** may be of the regenerative pump type. Referring to FIGS. **1-4**, in the illustrated embodiment, the pump assembly **10** may include an impeller **12**, a motor **14**, a housing **16**, and a diverter **18**.

Referring in particular to FIG. **3** where a part of the housing **16** is removed for demonstrative purposes, the impeller **12** may be located in the housing and may be rotated by the motor **14** about an axis of rotation R during use of the pump assembly **10**. Generally speaking, the impeller **12** may have a somewhat cylindrical shape that defines directions with respect to the shape including a radial direction, an axial direction, and a circumferential direction; as used herein, and unless otherwise specified, the terms radially, axially, circumferentially, and variants thereof, are in reference to the shape of the impeller. The impeller **12** may have different designs and constructions, including that shown in FIGS. **3** and **5**. In these figures, the impeller **12** has a body which may have a hub **20** and numerous vanes **22** extending radially outwardly from the hub. The hub **20** may be constructed for connection to a spinning shaft of the motor **14**. The vanes **22** may extend circumferentially all-around the hub **20**, and may each have a terminal end **24** at a radially-outwardly-most point of the vane. A circumferential periphery **26** may be an imaginary radially-outwardly-most circumference of the impeller **12**, and in this embodiment may be defined in part by the terminal ends **24** of the vanes **22**. The circumferential periphery **26** may have an axial height dimension A (FIG. **6**) which, in this embodiment, is also the axial height dimension of the vanes **22** and of the impeller **12**. Lastly, the impeller **12** may also have a first axial face **28** and a second axial face **30**. The first and second axial faces **28**, **30** may be defined by planar surfaces located at opposite axially-outwardly-most ends of the impeller **12**.

The motor **14** may be located outside of the housing **16** and may be mounted to the housing, and may be connected to the impeller **12** in order to provide rotational drive thereto via its spinning shaft. The motor **14** is shown schematically in FIG. **2**. The motor **14** may be an electric d.c. motor, or may be another type.

The housing **16** may provide structural support for components of the pump assembly **10**. The housing **16** may have different designs and constructions, including that shown in FIGS. **1-3** and **6**. In these figures, the housing **16** may be composed of separate and distinct pieces that are attached together via fasteners, welding, heat staking, or other attachment ways. The pieces may be made of a plastic material, and may be formed by injection molding processes. The housing **16** may include a body piece **32**, a cover piece **34**, and an inlet piece **36**; in other embodiments, for example, the inlet piece could be unitary with the body or cover piece, and an outlet piece could also be provided. The body piece **32** may have a first bulged portion **38** that partly defines a fluid-flow passage, as discussed below, and likewise the cover piece **34** may have a second bulged portion **40** that partly defines a fluid-flow passage.

Furthermore, and as mentioned, the housing **16** may partly define fluid-flow passages of the pump assembly **10**. Referring now to FIGS. **4** and **6**, the housing **16** may have an inlet passage **42**, an outlet passage **44**, and a first and second primary passage **46**, **48** communicating between the inlet and outlet passages. In other embodiments not shown in the figures, the housing could have a single primary passage instead of two, and could have two inlet passages such as a housing inlet passage arranged generally radially and a cover inlet passage arranged generally axially as disclosed in United States Patent Application Publication Number 2010/0086396 assigned to this applicant BorgWarner Inc. The inlet passage **42** may receive incoming fluid-flow and may be defined by an inlet surface **50**. The inlet passage **42** may have a generally cylindrical shape, and in one example may have a diameter dimension of approximately 20 mm; other diameter dimensions are possible and may depend on, among other factors, the particular application. The inlet passage **42** may have a longitudinal axis L_1 that may be arranged generally orthogonal to the axis of rotation R of the impeller **12**. The orthogonal relationship may include a radial inlet design where the longitudinal axis L_1 intersects the axis of rotation R, a tangential inlet design where the longitudinal axis L_1 is directed generally tangentially relative to the circumferential periphery **26**, and where the longitudinal axis L_1 is directed at an angular position therebetween; these orthogonal relationships are disclosed in the International Publication Number WO 2009/006385 to this applicant BorgWarner Inc. In FIG. **6**, incoming fluid-flow travels from left to right in the inlet passage **42**. The outlet passage **44** may carry outgoing fluid-flow expelled out of the pump assembly **10**, and may communicate with the first and second primary passages **46**, **48** at a location downstream that at which the inlet passage **42** communicates with the first and second primary passages. The outlet passage **44** may be defined by an outlet surface **52**, and, like the inlet passage **42**, may have a generally cylindrical shape.

The first and second primary passages **46**, **48** may carry fluid-flow through the pump assembly **10** as the fluid-flow travels from the inlet passage **42** and to the outlet passage **44**. Referring to FIG. **6**, in assembly the first primary passage **46** may be defined in part by a first primary surface **54** that, in this embodiment, may be located in the body piece **32** and may be formed by the first bulged portion **38**. The first axial face **28** of the impeller **12** may also define a part of the first primary passage **46**. Likewise, the second primary passage **48** may be defined in part by a second primary surface **56** that, in this embodiment, may be located in the cover piece **34** and may be formed by the second bulged portion **40**. The second axial face **30** of the impeller **12** may also define a part of the second primary passage **48**. In cross-sectional profile like that shown in FIG. **6**, each of the first and second primary passages **46**, **48** may have a generally half-circle shape. From the inlet passage **42** to the outlet passage **44**, each of the first and second primary passages **46**, **48** may have an abridged generally half-torus shape. Where the first primary passage **46** initially communicates with the inlet passage **42**, the first primary surface **54** and the inlet surface **50**, in a sense, may be continuous extensions of each other—that is to say, the transition between the surfaces **50**, **54** may be without structures that could interfere with fluid-flow from the inlet passage and to the first primary passage. Similarly, where the second primary passage **48** initially communicates with the inlet passage **42**, the second primary surface **56** and the inlet surface **50** may be continuous extensions of each other. The first and second primary passages **46**, **48** may each be open to the vanes **22** so that the first and second primary passages can communicate with the spaces located between neighboring individual vanes.

The diverter **18** may be a structure that may be used to veer, obstruct, or both, fluid-flow traveling through the inlet passage **42**. In the case of an air pump assembly, air flow may principally make its way into the spaces located between neighboring individual vanes **22** via the first and second primary passages **46**, **48** at the first and second axial faces **28**, **30** of the impeller **12**. It has been found that turbulent flow may be generated by initial impingement between incoming fluid-flow and the terminal ends **24** of the rotating vanes **22**, and it has been found that turbulent flow may be generated by initial impingement between incoming fluid-flow and the rotating vanes at the first and second axial faces **28**, **30**. The turbulent flow can spread beyond the region of immediate impingement and can interfere with and impede fluid-flow entering the first and second primary passages **46**, **48** from the inlet passage **42** at entrances **62**, **64** thereof (FIG. **6**). The diverter **18** may therefore veer fluid-flow away from impingement with the terminal ends **24** and/or impingement with the axial faces **28**, **30**, may be an obstruction to impingement, or both, to thereby limit or altogether eliminate turbulent flow generated thereat. Fluid-flow may then enter the first and second primary passage **46**, **48**, with greater ease and yielding improved fluid-flow efficiencies by as much as approximately eleven percent over known inlet designs without diverters; fluid-flow improvements greater than eleven percent may also be possible.

The diverter **18** may have different designs and constructions, including that shown by a first embodiment in FIGS. **4**, **5**, and **6**. The diverter **18** may be made of a plastic material, and may be formed by an injection molding process. The diverter **18** may be located in the inlet passage **42**, and may be attached to or extend from the inlet piece **36** at the inlet surface **50**, or may be attached to or extend from the body piece **32** or the cover piece **34**. The diverter **18** may have a longitudinal axis L_2 that may be in alignment with the longitudinal axis L_1 of the inlet passage **42**, and may also be in alignment with an imaginary radius of the impeller **12** that is positioned at an axial centerline of the impeller. In the inlet passage **42**, in the first embodiment, the diverter **18** may be positioned so that it does not directly obstruct the entrances **62**, **64** from fluid-flow into the first and second primary passage **46**, **48** from a generally radial incoming direction.

Referring to FIGS. **4-6**, in the first embodiment the diverter **18** may have a generally triangular or cone shape. The diverter **18** may have a first radial end **66** and a second radial end **68**, and may have a first circumferential end **70** and a second circumferential end **72**. The first radial end **66** may be rounded to facilitate fluid-flow over it. Further, the diverter **18** may have a first face surface **74** and a second face surface **76**, and may have a confrontation surface **78**. The first face surface **74** may be directed generally axially upwardly, and the second face surface **76** may be directed generally axially downwardly. In this first embodiment, the first and second face surfaces **74**, **76** may be generally planar, and may diverge away from each other from the first radial end **66** toward the second radial end **68**, which may form a tapered profile from the second radial end to the first radial end.

The confrontation surface **78** may directly confront the terminal ends **24** of the vanes **22** and the circumferential periphery **26** via a radial space. The radial space may have a radial length B that may be maintained at a constant dimension along its axial extent between the edges of the first and second face surfaces **74**, **76** at the confrontation surface **78**, and may be maintained at a constant dimension along its circumferential extent between the edges of the first and second circumferential ends **70**, **72** in which case the confrontation surface may have a bowed and curved profile that follows the profile of the circumferential periphery **26**. In another embodiment, for example, the confrontation surface **78** may be generally planar in which case the radial length B dimension has a greater value at the edges of the first and second circumferential ends **70**, **72** than at a circumferential centerpoint between the edges of the first and second circumferential ends. The radial length B may have a value that is less than a radial length of the diverter **18**, and, in one example, the radial length B may be approximately 0.6 mm or 1.0 mm; in other examples, other values for the radial length B are possible including values less than 0.6 mm, greater than 1.0 mm, or between 0.6 mm and 1.0 mm. The confrontation surface **78** may be arranged generally axially, and may have an axial height dimension that may be approximately equal to the axial height dimension A of the vanes **22** at the terminal ends **24**. Further, the confrontation surface **78** may have a circumferential width dimension C that may be substantially equal to or less than the diameter of the inlet passage **42**. The confrontation surface **78**, the circumferential periphery **26**, and the radial space therebetween, may constitute a confrontation region between the impeller **12** and the diverter **18**.

In use, fluid-flow is drawn into the inlet passage **42** via the rotating impeller **12**. As the fluid-flow encounters the diverter **18**, a portion of fluid-flow F (FIG. **6**) may be veered to the first primary passage **46** via the first face surface **74**, and a portion of the fluid-flow F may be veered to the second primary passage **48** via the second face surface **76**. Because the diverter **18**—and in particular the confrontation surface **78**—may obstruct impingement between incoming fluid-flow F and the terminal ends **24** of the vanes **22**, turbulent flow is limited or altogether eliminated thereat and the fluid-flow enters the first and second primary passages **46**, **48** substantially unimpeded by the turbulent flow that would otherwise be generated without use of the diverter. In one embodiment, the circumferential width C of the diverter **18** may be substantially equal to or greater than the corresponding circumferential width of the first and second primary passages **46**, **48** at their entrances **62**, **64**, and the diverter may be positioned in circumferential alignment with the entrances of the first and second primary passages so that turbulent flow may be particularly limited or altogether eliminated thereat.

FIG. **7** shows a second embodiment of the pump assembly **10**. The second embodiment is similar to the first embodiment in many ways, and the similarities may not necessarily be repeated here for the second embodiment. One difference is the diverter **18**. In FIG. **7**, the diverter **18** may have first and second face surfaces **74**, **76** that may be concave in cross-sectional profile as shown in the figure. In other words, the first and second face surfaces **74**, **76** may have a bowed or curved cross-sectional profile. The cross-sectional profile of the diverter **18** in the second embodiment may facilitate fluid-flow thereover.

FIG. **8** shows a third embodiment of the pump assembly **10**. The third embodiment is similar to the first embodiment in many ways, and the similarities may not necessarily be repeated here for the third embodiment. One difference is the diverter **18**. In FIG. **8**, the diverter **18** may have a generally T-shape with a stem portion **80** and a head portion **82**. The head portion **82** may have a greater axial height dimension than the stem portion **80**, and the axial height dimension of the head portion may be approximately equal to the axial height dimension of the vanes **22** at the terminal ends **24**. The head portion **82** may have a first and second face surface **75**, **77** that may be arranged generally axially like the confrontation surface **78**. In use in the third embodiment, incoming fluid-flow may impinge the first and second face surfaces **75**, **77**, and some turbulent flow may be generated thereat. The amount of turbulent flow generated, however, may be less than that generated by impingement between incoming fluid-flow and the terminal ends **24** of the rotating vanes **22** in the known inlet design without a diverter, and may therefore be acceptable in at least some applications.

FIG. **9** shows a fourth embodiment of the pump assembly **10**. The fourth embodiment is similar to the first embodiment in many ways, and the similarities may not necessarily be repeated here for the fourth embodiment. One difference is the diverter **18**. In FIG. **9**, the housing **16** has been turned one-hundred-and-eighty degrees relative to the depiction in FIG. **6**. The diverter **18** in the fourth embodiment may have first and second face surfaces **74**, **76** that may be generally planar and may be arranged generally radially. The confrontation surface **78** may have an axial height dimension that may be less than the axial height dimension of the vanes **22** at the terminal ends **24**, and may be less than approximately one-half the axial height dimension of the vanes at the terminal ends. In use in the fourth embodiment, incoming fluid-flow may impinge the terminal ends **24** of the vanes **22** at locations where the confrontation surface **78** does not confront the terminal ends, and some turbulent flow may be generated thereat. The amount of turbulent flow generated, however, may be less than that generated by impingement between incoming fluid-flow and the terminal ends **24** of the rotating vanes **22** in the known inlet design without a diverter, and may therefore be acceptable in at least some applications.

FIG. **10** shows a fifth embodiment of the pump assembly **10**. The fifth embodiment is similar to the fourth embodiment. One difference is the second radial end **68** and the confrontation surface **78** of the diverter **18**. The second radial end **68** may have a rounded profile, and the confrontation surface **78** may therefore also have a rounded profile.

FIG. **11** shows a sixth embodiment of the pump assembly **10**. The sixth embodiment is similar to the fourth embodiment. One difference is the second radial end **68** and the confrontation surface **78** of the diverter **18**. The second radial end **68** may have a pointed profile, and the confrontation surface **78** may therefore also have a pointed profile.

FIG. **12** shows a seventh embodiment of the pump assembly **10**. The seventh embodiment is similar to the first embodiment in many ways, and the similarities may not necessarily be repeated here for the seventh embodiment. One difference is the diverter **18**. In FIG. **12**, the diverter **18** may have a first extension or second diverter **84** and may have a second extension or third diverter **86**. The second and third diverters **84**, **86** may extend generally radially from the remaining portion of the diverter **18**. The second diverter **84** may have a second confrontation surface **88**, and the third diverter may have a third confrontation surface **90**. The second confrontation surface **88** may directly confront the first axial face **28** of the impeller **12** via an axial space, and the third confrontation surface **90** may directly confront the second axial face **30** via an axial space. The axial spaces may have a value of approximately 0.35 mm, 0.6 mm, 1.0 mm, or some other value more, less, or somewhere in between these values. The second and third confrontation surfaces **88**, **90** may each have a radial length dimension that may be approximately equal to a radial length dimension of the vanes **22** so that the second and third diverters **84**, **86** may radially overlap the radial extent of the vanes; in other embodiments, the radial length dimensions of the second and third confrontation surfaces may be greater or less than that of the vanes. Further, the Confrontation surfaces **88**, **90** may have a circumferential width dimension that may be substantially equal to that of the remaining portion of the diverter **18**, that may be substantially equal to or less than the diameter of the inlet passage **42**, or that may be substantially equal to the circumferential widths of the first and second primary passages **46**, **48** at their entrances **62**, **64**. In use, the second and third confrontation surfaces **88**, **90** may obstruct impingement between incoming fluid-flow and the axial faces **28**, **30** of the rotating vanes **22**, turbulent flow may be limited or altogether eliminated thereat, and the fluid-flow may enter the first and second primary passages **46**, **48** substantially unimpeded by the turbulent flow that would otherwise be generated without use of the second and third. diverters **84**, **86**. The functionality of the remaining portion of the diverter **18** with respect to the circumferential periphery **26** has been previously described. In alternatives to the seventh embodiment, only one of the second and third diverters **84**, **86** need be provided and not necessarily both of them.

FIG. **13** shows an eighth embodiment of the pump assembly **10**. The eighth embodiment is similar to the seventh embodiment. One difference is that the remaining portion of the diverter **18** is not provided, leaving only the second and third diverters **84**, **86**.

In other embodiments not shown in the figures, for example, the longitudinal axis of the diverter need not be in alignment with the longitudinal axis of the inlet passage, and instead the diverter of FIG. **9** could be slanted such that its axial height measured in the axial direction from its first radial end to its second radial end is approximately equal to the axial height of the vanes.

The following is a description of select illustrative embodiments within the scope of the invention. The invention is not, however, limited to this description; and each embodiment and components, elements, and steps within each embodiment may be used alone or in combination with any of the other embodiments and components, elements, and steps within the other embodiments.

Embodiment one may include an air pump assembly. The air pump assembly may comprise an impeller, a housing, and a diverter. The impeller may have an axial face, an axis of rotation, and a circumferential periphery. The housing may surround the impeller, and may form a part or more of a primary passage. The primary passage may be open to the impeller at the axial face. The housing may have an inlet passage that may communicate with the primary passage.

The inlet passage may have a longitudinal axis that may be arranged generally orthogonal to the axis of rotation of the impeller. The diverter may be located near or closer to the inlet passage. The diverter may have a surface that may confront the axial face of the impeller, may confront the circumferential periphery of the impeller, or may confront both the axial face and the circumferential periphery. During use of the air pump assembly, the diverter may inhibit the generation of turbulent flow between incoming air and the impeller where the surface confronts the impeller.

Embodiment two, which may be combined with embodiment one, further describes that the air pump assembly may include a motor connected to the impeller to rotate the impeller during use of the air pump assembly.

Embodiment three, which may be combined with any one of embodiments one and two, further describes that the axial face may include a first axial face and a second axial face. The primary passage may include a first primary passage and a second primary passage. The first primary passage may be open to the impeller at the first axial face and the second primary passage may be open to the impeller at the second axial face. The inlet passage may communicate with the first and second primary passages.

Embodiment four, which may be combined with any one of embodiments one, two, and three, further describes that the housing may include a body piece and a cover piece that are attached together.

Embodiment five, which may be combined with any one of embodiments one, two, three, and four, further describes that the surface of the diverter confronts the circumferential periphery and may have an axial height dimension that may be greater than approximately one-half an axial height dimension of the impeller at the circumferential periphery.

Embodiment six, which may be combined with any one of embodiments one, two, three, four, and five, further describes that the surface of the diverter confronts the circumferential periphery and may be spaced radially from the circumferential periphery by a distance that may be less than a radial length dimension of the diverter.

Embodiment seven, which may be combined with any one of embodiments one, two, three, four, five, and six, further describes that the surface of the diverter confronts the circumferential periphery and that a distance of a radial space between the surface of the diverter and the circumferential periphery may be maintained generally constant from a first circumferential end of the diverter to a second circumferential end of the diverter.

Embodiment eight, which may be combined with any one of embodiments one, two, three, four, five, six, and seven, further describes that the surface of the diverter confronts the circumferential periphery of the impeller and may have a circumferential width dimension that may be greater than approximately one-half a diameter dimension of the inlet passage.

Embodiment nine, which may be combined with any one of embodiments one, two, three, four, five, six, seven, and eight, further describes that the surface of the diverter confronts the circumferential periphery of the impeller and may have an axial height dimension that may be greater than an axial height dimension of an end of the diverter that is initially impinged by incoming air flow flowing through the inlet passage.

Embodiment ten, which may be combined with any one of embodiments one, two, three, four, five, six, seven, eight, and nine, further describes that the surface of the diverter confronts the circumferential periphery and that the diverter may have a first face surface and a second face surface. The first and second face surfaces may diverge away from each other in a direction toward the surface of the diverter confronting the circumferential periphery of the impeller.

Embodiment eleven, which may be combined with any one of embodiments one, two, three, four, five, six, seven, eight, nine, and ten, further describes that the surface of the diverter confronts the axial face of the impeller and confronts a portion or more of a radial extent of a plurality of vanes of the impeller.

Embodiment twelve may include a method. The method may comprise providing an air pump assembly that may comprise an impeller and a housing. The housing may surround the impeller. The impeller may have numerous vanes, an axial face, and an axis of rotation. The vanes may have a circumferential periphery. The housing may form a part or more of a primary passage, and the primary passage may be open to the vanes at the axial face. The housing may have an inlet passage that, may have a longitudinal axis that may be arranged generally orthogonal to the axis of rotation of the impeller. The method may further comprise diverting a portion or more of incoming air flow traveling through the inlet passage away from the circumferential periphery of the vanes, away from the axial face of the impeller, or away from both of the circumferential periphery and the axial face.

Embodiment thirteen, which may be combined with embodiment twelve, further describes diverting a portion or more of incoming air flow by way of a diverter that may be located partially or more within the inlet passage. The diverter may have a greatest axial height dimension that may be greater than approximately one-half an axial height dimension of the vanes at the circumferential periphery.

Embodiment fourteen, which may be combined with any one of embodiments twelve and thirteen, further describes diverting a portion or more of incoming air flow by way of a diverter that may be located partially or more within the inlet passage. The diverter may have a greatest circumferential width dimension that may be greater than approximately one-half a diameter dimension of the inlet passage.

Embodiment fifteen may include an air pump assembly. The air pump assembly may comprise an impeller, a motor, a housing, and a diverter. The impeller may have numerous vanes, a first axial face, a second axial face, and an axis of rotation. The vanes may have a circumferential periphery. The motor may be connected to the impeller in order to rotate the impeller when the air pump assembly is in use. The housing may surround the impeller. The housing may form a part or more of a first primary passage. The first primary passage may be open to the vanes at the first axial face. The housing may form a part or more of a second primary passage. The second primary passage may be open to the vanes at the second axial face. The housing may have an inlet passage that may communicate with the first and second primary passages. The housing may have an outlet passage that may communicate with the first and second primary passages. The inlet passage may have a longitudinal axis that may be arranged generally orthogonal to the axis of rotation of the impeller. The diverter may have a surface confronting the circumferential periphery of the vanes. The surface may have an axial height dimension that may be greater than approximately one-half an axial height dimension of the vanes at the circumferential periphery. The surface may have a circumferential width dimension that may be greater than approximately one-half a diameter dimension of the inlet passage. When the air pump assembly is in use, the diverter may inhibit incoming air flow at the circumferential periphery of the vanes where the surface confronts the circumferential periphery, and the diverter may veer incoming air flow to the first and second primary passages.

The above description of embodiments of the invention is merely illustrative in nature and, thus, variations thereof are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A product comprising:

a regenerative air pump assembly comprising:

an impeller having an axial face, an axis of rotation, and a circumferential periphery;

a housing surrounding the impeller;

an inlet and an outlet passage formed in the housing for receiving and delivering a fluid, the inlet passage having a longitudinal axis arranged generally orthogonal to the axis of rotation of the impeller;

at least one primary passage being open to the impeller at the axial face of the impeller and extending between the inlet passage and the outlet passage and having a cross-section defined by the axial face of the impeller and a primary surface of the housing;

wherein the cross-section of the at least one primary passage is essentially the same from the inlet passage to the outlet passage; and

a diverter located at least adjacent the inlet passage, the diverter having a surface confronting the axial face of the impeller, confronting the circumferential periphery of the impeller, or confronting the axial face and the circumferential periphery of the impeller, wherein, during use of the air pump assembly, the diverter inhibits generation of turbulent flow between the incoming fluid flow and the impeller where the diverter surface confronts the impeller.

2. A product as set forth in claim **1** wherein the air pump assembly comprises a motor connected to the impeller to rotate the impeller during use of the air pump assembly.

3. A product as set forth in claim **1** wherein the housing comprises a body piece and a cover piece that are attached together.

4. A product as set forth in claim **1** wherein the surface of the diverter confronts the circumferential periphery of the impeller and has an axial height dimension that is greater than approximately one-half an axial height dimension of the impeller at the circumferential periphery.

5. A product as set forth in claim **1** wherein the surface of the diverter confronts the circumferential periphery of the impeller and is spaced radially from the circumferential periphery by a distance that is less than a radial length dimension of the diverter.

6. A product as set forth in claim **5** wherein the distance of the radial space between the surface of the diverter and the circumferential periphery of the impeller is maintained generally constant from a first circumferential end of the diverter to a second circumferential end of the diverter.

7. A product as set forth in claim **1** wherein the surface of the diverter confronts the circumferential periphery of the impeller and has a circumferential width dimension that is greater than approximately one-half a diameter dimension of the inlet passage.

8. A product as set forth in claim **1** wherein the surface of the diverter confronts the circumferential periphery of the impeller and has an axial height dimension that is greater than an axial height dimension of an end of the diverter that is initially impinged by the incoming air flow flowing through the inlet passage.

9. A product as set forth in claim **8** wherein the diverter has a first face surface and a second face surface, the first and second face surfaces of the diverter diverging away from each other in a direction toward the surface of the diverter confronting the circumferential periphery of the impeller.

10. The product of claim **9** wherein the first and the second face surfaces of the diverter are concave.

11. The product of claim **9**, wherein the diverter further includes a first extension and a second extension, wherein the axial face includes a first axial face and a second axial face, and wherein the first extension faces a portion of the first axial face and the second extension faces a portion of the second axial face.

12. The product of claim **8** wherein the diverter is generally T-shaped.

13. A product as set forth in claim **1** wherein the surface of the diverter confronts the axial face of the impeller and confronts at least a portion of a radial extent of a plurality of vanes of the impeller.

14. The product of claim **1** wherein a greatest axial height of the diverter is less than half the axial height dimension of the impeller.

15. The product of claim **1** wherein the diverter comprises a first diverter and a second diverter, wherein the first diverter and the second diverter are separate components, wherein the axial face includes a first axial face and a second axial face, and wherein the first diverter confronts the first axial face and the second diverter confronts the second axial face.

16. The product of claim **1** further comprising a second axial face of the impeller, and wherein a second primary passage being open to the impeller at the second axial face extends between the inlet passage and the outlet passage.

17. A method comprising:

providing a regenerative air pump assembly comprising an impeller having an axial face, an axis of rotation, and a circumferential periphery; a housing surrounding the impeller, an inlet passage and an outlet passage formed in the housing for receiving and delivering a fluid, the inlet passage having a longitudinal axis arranged generally orthogonal to the axis of rotation of the impeller; at least one primary passage being open to the impeller at the axial face and extending between the inlet passage and the outlet passage and having a cross-section defined by the axial face of the impeller and a primary surface of the housing; wherein the cross-section of the at least one primary passage is essentially the same from the inlet passage to the outlet passage; and

diverting at least a portion of incoming fluid flow through the inlet passage directly into the at least one primary passage and away from the circumferential periphery of the impeller, away from the axial face of the impeller, or away from both the circumferential periphery and the axial face of the impeller.

18. A method as set forth in claim **17** further comprising diverting at least a portion of incoming air flow via a diverter located at least partially within the inlet passage, the diverter having a greatest axial height dimension greater than approximately one-half an axial height dimension of the impeller at the circumferential periphery of the impeller.

19. A method as set forth in claim **17** further comprising diverting at least a portion of incoming air flow via a diverter located at least partially within the inlet passage, the diverter having a greatest circumferential width dimension greater than approximately one-half a diameter dimension of the inlet passage.

20. A product comprising:

a regenerative air pump assembly comprising:

an impeller having a plurality of vanes, a first axial face, a second axial face, and an axis of rotation, the plurality of vanes having a circumferential periphery;

a motor connected to the impeller to rotate the impeller during use of the air pump assembly;

a housing surrounding the impeller,

an inlet passage and an outlet passage formed in the housing for receiving and delivering a fluid, the inlet passage having a longitudinal axis arranged generally orthogonal to the axis of rotation of the impeller;

a first primary passage being open to the impeller at the first axial face and extending between the inlet passage and the outlet passage and having a first cross-section defined by the first axial face of the impeller and a first primary surface of the housing and;

a second primary passage being open to the impeller at the second axial face and extending between the inlet passage and the outlet passage and having a second cross-section defined by the second axial face of the impeller and a second primary surface of the housing;

wherein the first cross-section of the first primary passage is essentially the same from the inlet passage to the outlet passage and the second cross-section of the secondary primary passage is essentially the same from the inlet passage to the outlet passage; and

a diverter having a surface confronting the circumferential periphery of the plurality of vanes, the surface having an axial height dimension greater than approximately one-half an axial height dimension of the plurality of vanes at the circumferential periphery, the surface having a circumferential width dimension greater than approximately one-half a diameter dimension of the inlet passage, wherein, during use of the air pump assembly, the diverter inhibits incoming air flow at the circumferential periphery of the plurality of vanes where the surface confronts the circumferential periphery, and the diverter veers incoming air flow to the first and second primary passages.

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